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Highly interconnected porous nanocomposite scaffolds manufactured by table-top 3D printing

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ABSTRACT

With the development and accessibility of commercial three-dimensional (3D) printers, the capability of manufacturing highly interconnected and porous 3D scaffolds holds significant interest and great potential in the biomedical field. Unfortunately, current table-top printing modalities are largely predicated on their more expensive commercial counterparts leveraging proven printing materials. Polylactic acid (PLA) is commercially used as a soluble support material, wherein intricate and complex parts requiring support during the build process are necessary. Based on this principle, we have developed a technique wherein highly porous and interconnected biocompatible hydrogels were readily manufactured via investment casting and shaped for use as an implantable scaffold. In addition, the current technique allows for the incorporation of bioactive nanomaterials for increased mechanical strength and enhanced biocompatibility. Therefore, for this study, a table-top fused deposition modeling 3D printer (Solidoodle3) was used to fabricate all PLA molds. A 35 mm x 35 mm x 5 mm cube with a 1.2-mm lip was designed in Rhinoceros3D® computer-aided drafting software. The CAD files were processed with varying infill densities of 0.2, 0.4, and 0.6, respectively, and subsequently 3D printed. Functionalized poly(ethylene glycol) diacrylate (PEG-Da) with photocrosslinkable unsaturated alkenes (MW = 530) in nonfunctionalized poly(ethylene glycol) (PEG, MW = 300) was used as a test material in the presence of a photoinitiator exhibiting excitation in the ultraviolet (UV) range. The PEG:PEG-Da mixture was cast upon the PLA molds and UV cured for 2 min on each side. Once fully crosslinked, the entire construct was ultrasonicated in tetrahydrofuran for 3 h at 40°C to allow for complete dissolution of the PLA mold. The highly porous PEG:PEG-Da scaffold was subsequently swelled in ultrapure water overnight to remove uncrosslinked PEG. Investment casting is a highly controlled method for the manufacture of 3D constructs requiring good precision and accuracy of internal porosity. To our knowledge, this is the first attempt at employing this technique through the combination of a table-top 3D printer and photocrosslinkable hydrogels. Initial analyses of the fabricated PEG-Da scaffolds illustrate excellent correlation with regards to the processed CAD model with high reproducibility and control of interconnected porous structures. The fabricated mats can be readily shaped and molded for a myriad of applications due to the flexibility in design and availability of functionalized PEG-based hydrogels. The current method is being employed for the manufacture of biphasic scaffolds for osteochondral defects. Based on the initial studies presented here, the extremely flexible methodology developed serves to further extend the application of table-top 3D printing technologies to manufacture 3D hydrogel-based complex scaffolds.